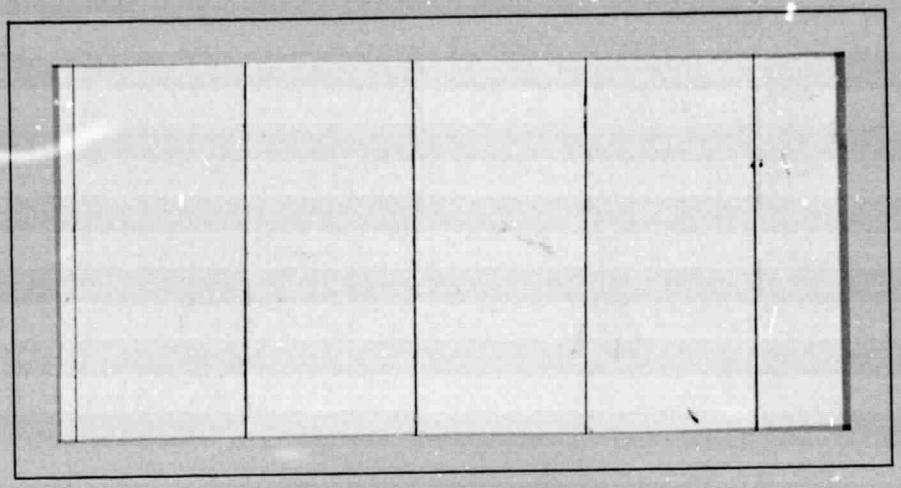

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DETERMINATION OF AEROSOL CONTENT IN THE ATMOSPHERE FROM LANDSAT DATA

Progress Report No. 3

Contract No. NAS5-20899

I. D. Number 22260

Period Covered: August 1 to October 31, 1975

Principal Investigator: Dr. M. Griggs

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P. O. Box 2351
La Jolla, CA 92038

Prepared for:

Goddard Space Flight Center

ACCOMPLISHMENTS

In this third reporting period more theoretical calculations were made, and Volz measurements were made at both test sites.

Theoretical Calculations

The Dave program was used to calculate the radiance-aerosol content relationship for MSS 4, 5 and 7. It was found in the calculations for MSS 6 (see Progress Report No. 1) that the results for a size distribution with $\nu = 4$ agree closely with the measured radiance-aerosol content relationship. Hence calculations for MSS 4, 5 and 7 were made using $\nu = 4$, and refractive index of $1.5 + 0i$.

The calculated relationships are shown in Figure 1 in comparison with the measured relationships. The measured and calculated data were made to agree at N = 0 (i.e. a pure Rayleigh atmosphere) by choosing the appropriate albedo in the theoretical calculations. The values of A = 0, A = 0, and A = 0.005 for MSS 7, 6 and 5 respectively look reasonable on the basis of published estimates of A (e.g. R. J. Curran, Appl. Opt. 11, 1857, 1972). However, the value of A = 0.06 for MSS 4 appears high by a factor of 4 (compared to clear water), and suggests that the measured radiance values in MSS 4 are influenced by suspended matter in the water. Indeed, the MSS 4 wavelength (0.55 μm) is one selected for chlorophyll observations (see R. J. Curran), and is the channel which most clearly shows the presence of water turbidity in the MSS data. Although the effective surface reflectivity appears high, the slopes of the theoretical and measured relationships agree very well, suggesting that for MSS 4 the reflectivity of naturally occurring water is always significantly higher than that published for clear water.

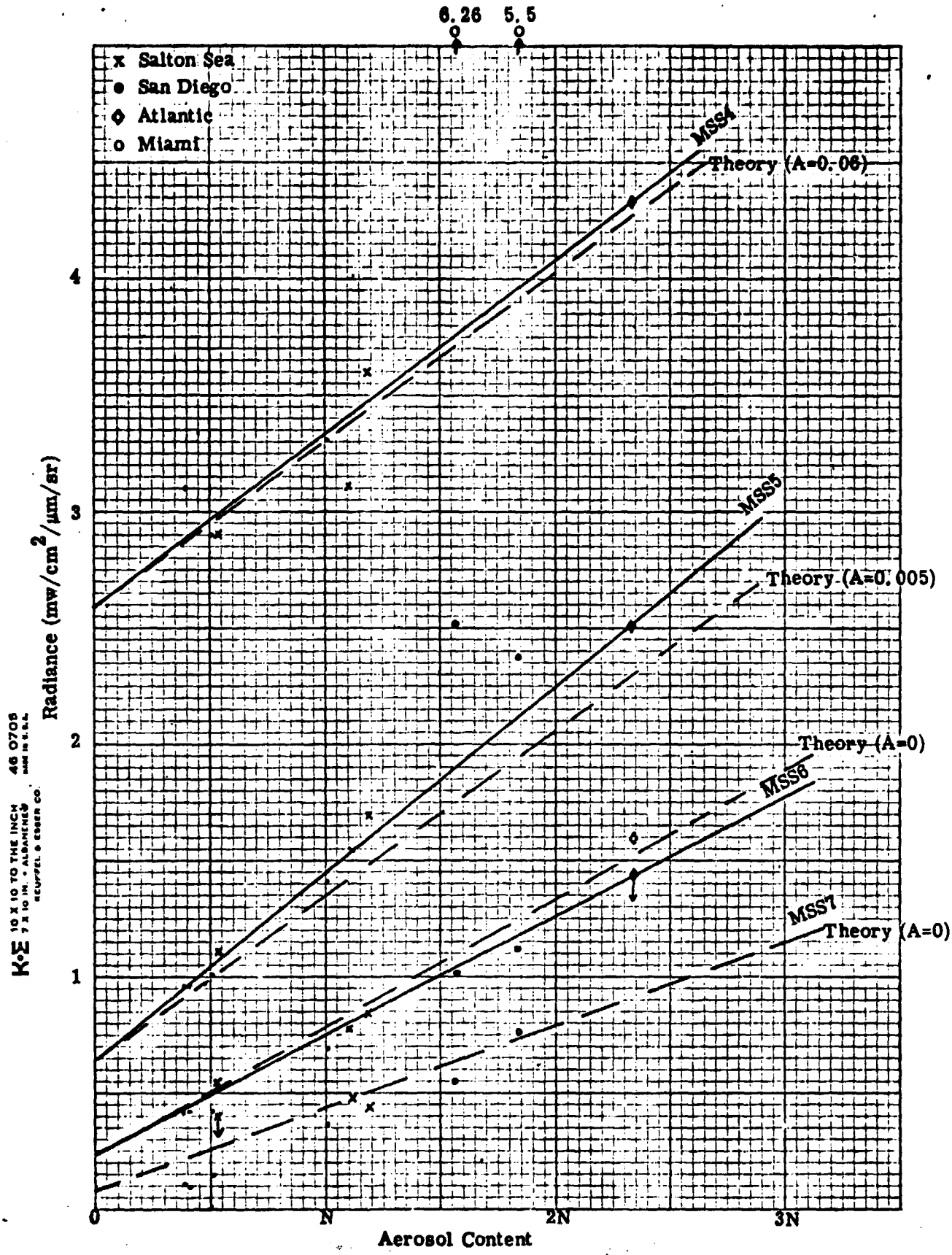

Figure 1. Landsat 1 Data Compared to Theoretical Calculations

Water Vapor Effects in MSS 7 -- Figure 1 shows that most of the measured radiances for MSS 7 are lower than predicted by theory. This is expected since there is significant absorption by water vapor in this bandpass, which is not accounted for in the Dave program.

Pitts et al. (9th Remote Sensing Symposium, Ann Arbor, April 1974) calculated the atmospheric transmission for the MSS 7 channel as a function of water vapor content. Their results, based on high spectral resolution calculations, are shown in Figure 2, and agree well with band model calculations by Marggraf and Griggs (J. Atmos. Sci. 26, 469, 1969). The upwelling radiation traverses approximately (1 + sec θ) airmasses where θ is the sun zenith angle. Hence for the sun angle of 63.26° ($\cos\theta = .45$), to which the radiance-aerosol content relationship is normalized, the radiation traverses 3.2 airmasses. The Gutnick model water vapor distribution has a vertical water vapor content of 1.7 cm, so that the radiation traverses 5.5 cm with a transmission of 0.81, according to Figure 2.

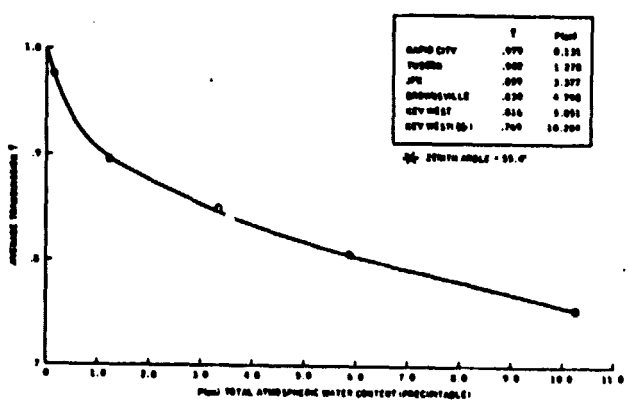

Figure 2. Effect of Water Vapor on the ERTS MSS 7 Band.

Of course, the actual water vapor content at the time of Landsat data will deviate from the Gutnick model value. For typical water vapor contents we might assume, from Figure 2, the transmission factor to be applied to the MSS 7 data to be 0.85 ± 0.1. However, since the present investigation is basically empirical, and the range of transmission values is small, it is not considered necessary to adjust the MSS 7 radiance data for water vapor effects.

Oxygen Absorption in MSS 6 -- The MSS 6 bandpass includes the 0.76 μm oxygen band so that the MSS 6 radiance will be reduced from that computed by the Dave program which neglects oxygen absorption. Based on the oxygen absorption data of Saiedy et al. (Appl. Opt. 4, 497, 1965) the absorption by oxygen in the MSS 6 channel is about 5% for 3.2 airmasses. Since the oxygen concentration in the atmosphere is essentially constant, its absorption has no significant effect on the present investigation.

Volz Measurements

In this period, it was possible to obtain Volz data for three of the five Landsat 2 overpasses at the San Diego test site. One trip was made to the Salton Sea test site and good data were obtained. Data were also obtained for two Landsat 1 overpasses at San Diego. These Volz data are given in Table 1.

Aircraft Measurements

No aircraft flights with the Exotech radiometer were made in this period, since the Landsat digital data still have not been received for comparison with the previous two sets of aircraft data. It is planned to verify the usefulness of the aircraft measurements in conjunction with the Landsat data before making further aircraft flights.

TABLE 1. Volz Data

	Date	Aerosol Optical Thickness	Aerosol Content
LANDSAT 2			
San Diego	8-21-75	.253	1.19 N
	9-26-75	.284	1.33 N
	10-14-75	.136	.64 N
Salton Sea	10-31-75	.116	.54 N
LANDSAT 1			
San Diego	8-30-75	.173	.81 N
	9-17-75	.193	.91 N

The B&W prints were received and examined for the overpasses coinciding with the aircraft measurements. The Salton Sea aircraft data suggested that the water was polluted on 6-27-75 (see Progress Report No. 2), but the B&W prints shows relatively minor pollution, in comparison with B&W prints of other overpasses. The B&W print for San Diego on 7-16-75 showed no evidence of pollution.

The aircraft measurements made at San Diego under hazy conditions on 7-16-75 were analyzed, and found to show wide variability in the radiance values. Correlating sharp peaks were observed in all four channels with amplitudes as great as five times larger than the mean value. These peaks had about 50 ft half widths, and are presumably due to sun glitter or patches of water with different reflectivities. The amplitudes of the peaks did not appear to depend on the flight direction suggesting that sun glitter is not responsible. An

example of the data is presented in Figure 3, which shows the recordings for MSS 4 and 5 obtained at 100 ft altitude over about a 1.6 mile flight path (chart speed: 15 cm/min.; airspeed: 90 mph). These data are in sharp contrast to the smooth data of Figure 4, obtained at the Salton Sea (6-27-75) under the same conditions. Visually, the water surface appeared similar for both dates.

The spectral variation of the San Diego data based on mean values for each run (about 1.5 miles) is shown in Figure 5. The data show a slight tendency to peak at MSS 6, but not so clearly as at the Salton Sea. MSS 4 and 7 show about the same radiance values, while the MSS 5 and 6 values are generally lower at San Diego than at the Salton Sea (compare with Figure 2 of Progress Report No. 2).

Further analyses of these data will be made when the Landsat digital data are received.

Landsat Data

Digital data for three Landsat 2 overpasses at San Diego have been received and analyzed; CCT's for three other overpasses at San Diego and Salton Sea are on order. A CCT ordered for the Salton Sea 5-22-75 overpass (I.D. 2120-17382) is not available since MSS 4 did not produce acceptable data, and a CCT was not generated by NASA.

The radiance data analyzed to date are shown in Figure 6 as a function of aerosol content. These data are based on calibration data obtained from NASA-GSFC with the help of Mr. H. Oseroff, and take into account the change in calibration made by NASA on July 16, 1975. The calibrations are quite different from Landsat 1, in that there is an offset at zero count, i.e., at zero count the radiance has

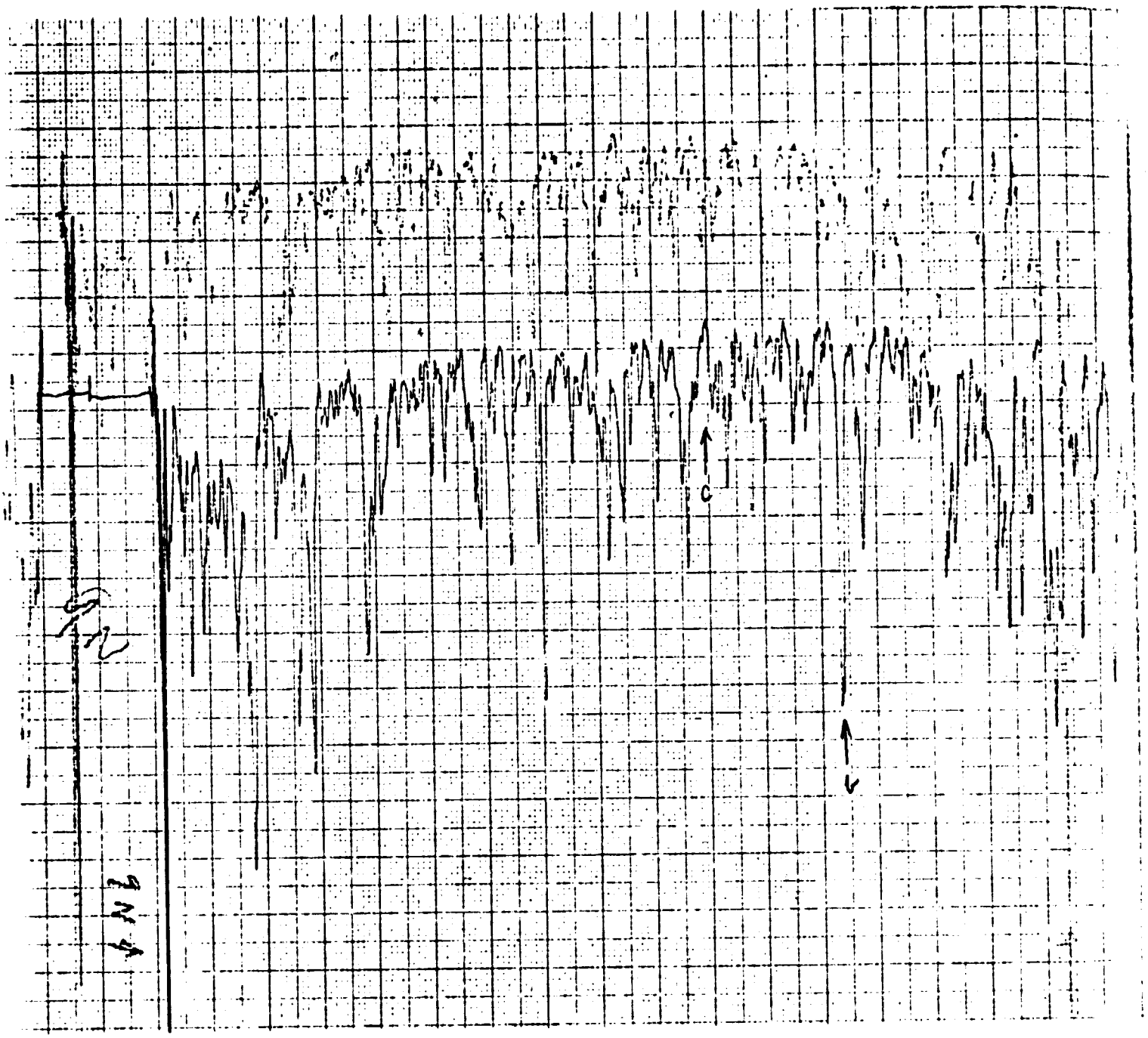

Figure 3. San Diego Aircraft Data 7-16-75.

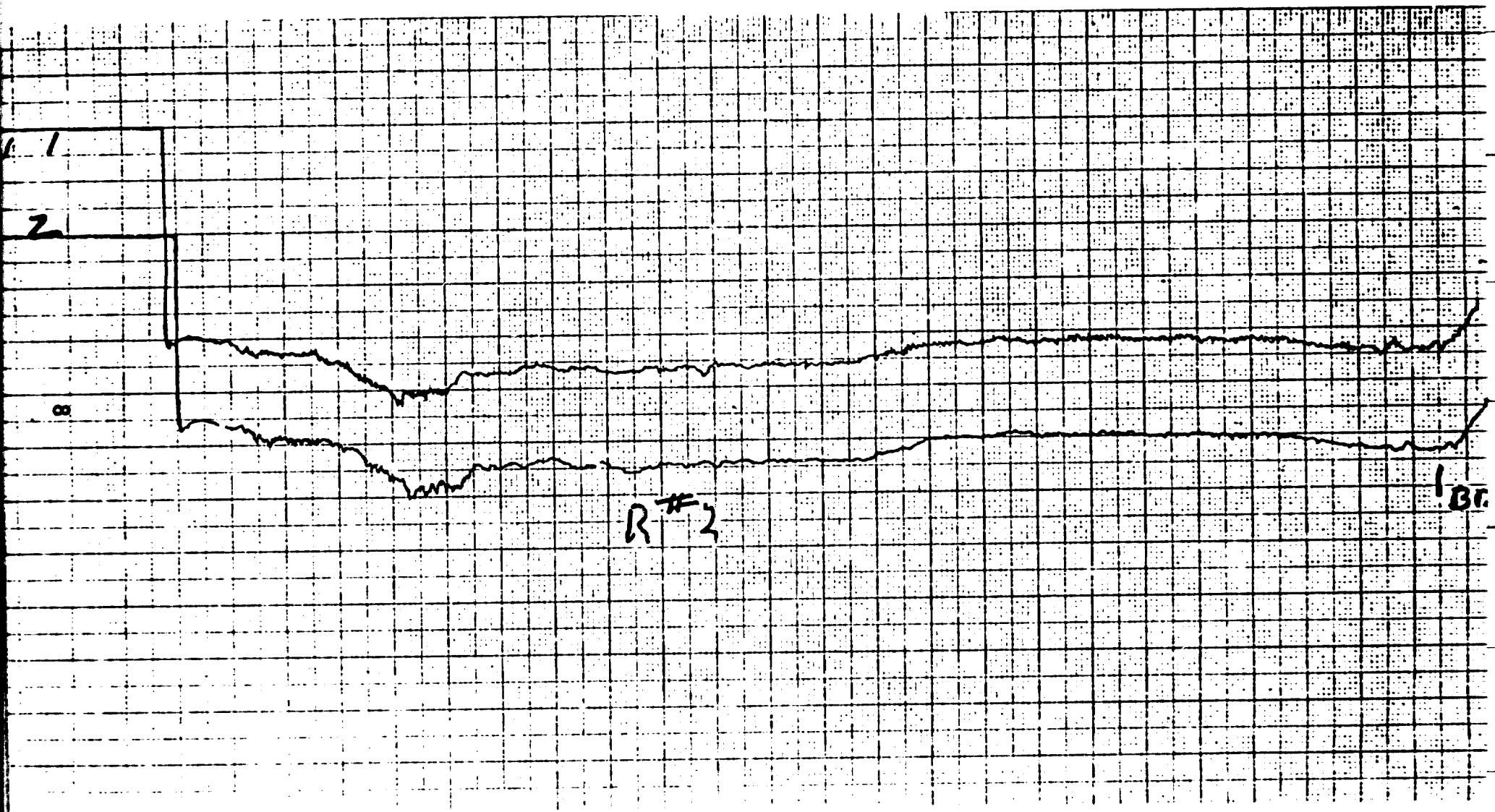

Figure 4. Salton Sea Aircraft Data 6-27-75.

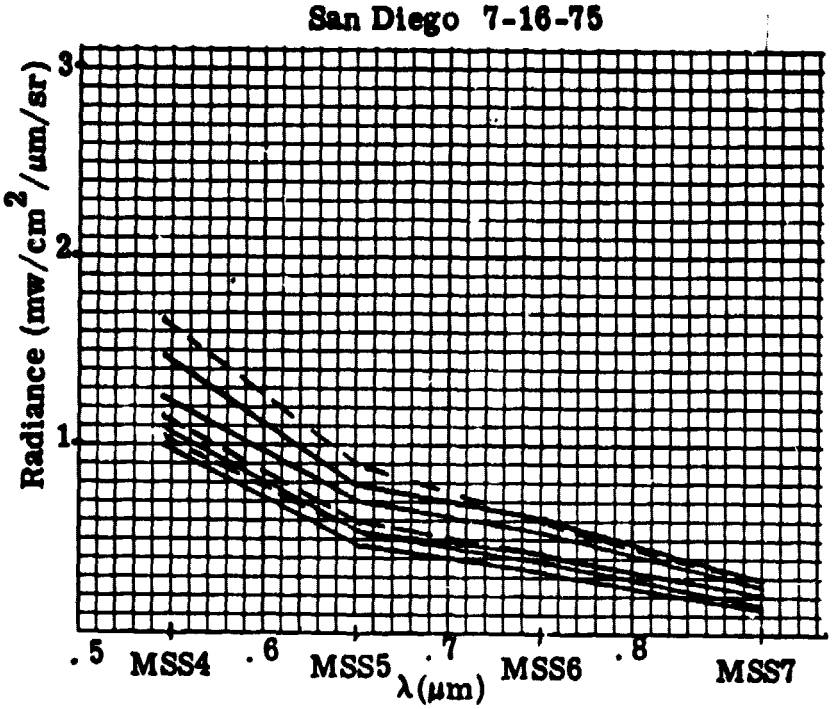

Figure 5. San Diego Ocean Radiances Measured from Aircraft 7-16-75

a small but significant value. The equations relating radiance R ($mw/cm^2/\mu m\ sr$) and counts C are given in Table 2.

It should be noted that, since the CCT's do not print negative count values, that the current system does not allow for radiances below .06 $mw/cm^2/\mu m/sr$. It is seen from Figure 1 that for Landsat 1 MSS 6 and 7 there were 12 values less than this. This apparent limitation in the Landsat 2 data will be further evaluated.

TABLE 2. Radiance-Count Relationships

MSS 4	R	=	.8 + .2008C
MSS 5	R	=	.6 + .1339C
MSS 6	R	=	.6 + .1150C
MSS 7	R	=	.61 + .3360C

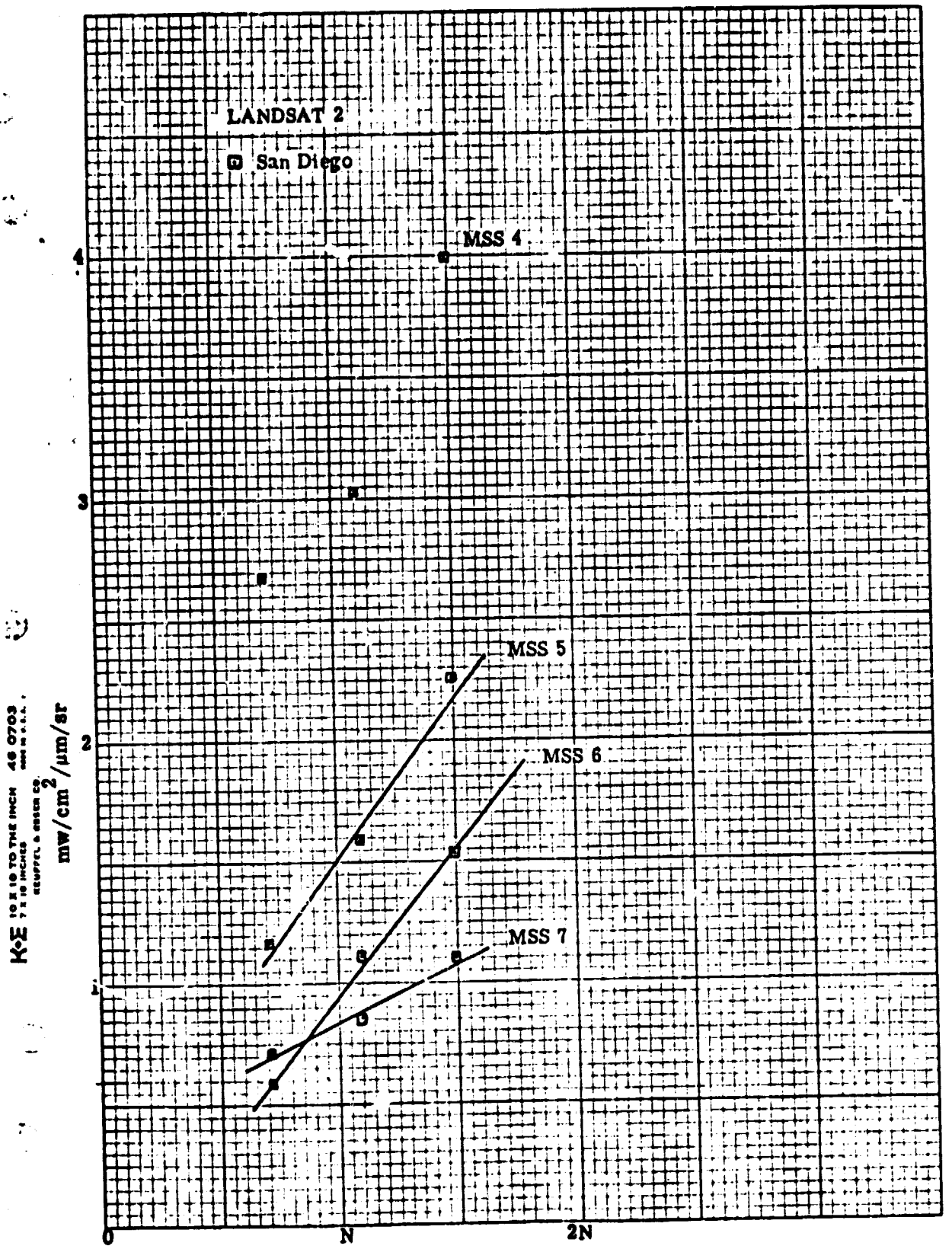

Figure 6. Landsat 2 Radiance vs. Aerosol Content

In Figure 6 the Landsat 2 data do not show the same relationships as Landsat 1 (Figure 5). However, only three overpasses have been analyzed to date, and further evaluation of the data will be made when more overpasses are analyzed.

Plans

Volz data will be taken at both test sites, weather permitting. Analysis of the digital data will continue, and the calibration procedures will be further evaluated.

SIGNIFICANT RESULTS

There are no significant results to report in this period.

PUBLICATIONS

No publications were made in this period.

RECOMMENDATIONS

No changes in the program appear necessary at the present time.

DATA USE

Value of Data Allowed	Value of Data Ordered	Value of Data Received
$ 6500.	$ 1806.	$ 1206.

PROBLEMS

No problems exist at the present time.